Mother's Milk and Sewage: Their Interactive Effects on Infant Mortality

Jean-Pierre Habicht, MD, Julie DaVanzo, PhD, and William P. Butz, BA

From the RAND Corporation, the Economics and Statistics Department, Santa Monica, California, and Division of Nutritional Sciences and Agricultural Experiment Station, Cornell University, Ithaca, New York

ABSTRACT. If they lived in households without piped water or a toilet, Malaysian infants who did not breast-feed were five times more likely to die after 1 week of age than those who breast-fed, when other significant factors affecting infant mortality were taken into account. This is double the relative risk associated with not breast-feeding for infants born into households with toilets, whether or not they had piped water. Analogously, improvements in toilet sanitation appear to have reduced mortality twice as much among infants who did not breast-feed as among those who did. These findings, from a retrospective survey of infants born to a probability sample of 1,262 women in peninsular Malaysia, confirm the pernicious synergistic effect of poor sanitation and nonbreastfeeding that was postulated previously on theoretical grounds. Promoting and maintaining high initiation of breast-feeding is thus particularly important where poor sanitation is prevalent. Even more affluent areas should not be neglected, however, because socioeconomic improvement, including improved environmental sanitation, is often accompanied by decreased breast-feeding. Although the risk to each nonbreast-fed infant was less in those areas, infants there were less likely to breast-feed in Malaysia, and hence they made up a significant proportion of lives that could be saved by breast-feeding. *Pediatrics* 1988;81:456–461; *breast-feeding, infant mortality, sanitation, developing country.*

We present evidence that the lack of breast-feeding and poor environmental sanitation have a pernicious synergistic effect on infant mortality. We showed elsewhere that curtailed breast-feeding was a major correlate of infant mortality in peninsular Malaysia before 1975.[1] Results of this study indicate that infants who did not breast-feed and who lived in households with poor sanitation were at higher risk of death than breast-fed infants who lived in households with adequate sanitation. Authors[2] of the Report of the Task Force on the Assessment of the Scientific Evidence Relating to Infant-Feeding Practices and Infant Health postulated this on theoretical grounds—that curtailed breast-feeding results in the feeding of polluted breast milk substitutes and other foods, especially where environmental sanitation is poor, and that protective factors in mother's milk are particularly necessary where exposure to gastrointestinal infections is high.[3] Comparisons of studies[2] done in populations with high and low exposure to diarrhea indicate that the benefits of breast-feeding in reducing gastrointestinal illnesses are best seen in populations in which these diseases are common. Such cross-study comparisons, however, are fraught with uncertainties in comparability. No single study differentiated between households with good and bad sanitary conditions, and we have found no studies to date that show how these differences in sanitation might affect the impact of breast-feeding on infant mortality.

METHODS

We used data from the 1976 to 1977 Malaysian Family Life Survey,[4] a probability survey of 1,262 households in peninsular Malaysia that each contained an ever-married woman 50 years of age or younger. The sample here was restricted to children born to these women at least 1 year before the survey. We tabulated the number of deaths reported by recall that occurred between the first week and 1 year of age among infants born to these households according to whether the babies

Received for publication Nov 24, 1986; accepted May 5, 1987.
Reprint requests to (J.-P.H.) Savage Hall, Cornell University, Ithaca, NY 14853.

had breast-fed and whether their households had both a toilet and piped water, only a toilet, or neither. We omit from our sample here babies born into households with only piped water because of small sample size (only 24 such babies did not breast-feed and one died). Our sample for analysis consisted of 5,141 infants, of whom 165 died between 1 week and 1 year of age. These recall data appeared generally valid because the associations of breast-feeding with postpartum amenorrhea[5] and of infant mortality with its determinants[6] corresponded to associations found in prospective studies.

In the sample analyzed here, 84% of the children breast-fed. The data also contained information about the toilet and water facilities in the household at the time of the child's birth. In these data, a toilet system of any kind (whether flush or nonflush, exclusive to the household or shared) in contrast to no toilet (whether disposal was on the ground or in rivers or canals) best discriminated differences in infant mortality. Households with some kind of toilet accounted for 79% of the infants in this sample. Similarly, piped water (whether inside or outside the house, whether exclusive to the household or not) and no piped water (whether from well or rivers or canals) best discriminated infant mortality differences. Households with piped water accounted for 42% of the infants in this sample.

Postperinatal infant mortality rates (from 1 week to 1 year of age) are presented separately within each of the three water/toilet groups according to whether the child ever breast-fed. We ignored deaths during the first week of life because they were unlikely to be due to the type of feeding and because the conditions that caused them may have precluded breast-feeding[1]; this study was concerned with the opposite direction of causality.

Inferences were drawn from one-tailed statistical tests ($P < .05$) because of the strong presumption that breast-feeding decreases infant mortality and that the ill effects of not breast-feeding and poor water and sanitation are synergistic. For the same reasons, the confidence limit was the one-tailed 95% confidence limit.

The relative risk of dying between 1 week and 1 year of age for those who never breast-fed compared with those who did is the ratio of their respective mortality rates.[7] The relative risk assumes a proportional increase in risk for each infant who did not breast-feed. The lower confidence limit for each relative risk was calculated from the corresponding confidence level of the relative odds.[8] The statistical significances of the differences among the risks of the three water/toilet categories were estimated from t tests of the logarithms of the odds ratio and their variances.

The attributable risk of mortality due to not breast-feeding is the difference between the mortality rate of those who did not and who did breast-feed[7] and is an estimate in a population of the number of lives (per 1,000 infants) that breast-feeding would save. The lower confidence limit was calculated according to the conventional method as were the statistical significances of differences among water/toilet categories.[8]

These mortality rates, and attributable and relative risks, were influenced by many other factors in addition to the lack of breast-feeding or water and sanitation. Many such factors were measured in the Malaysian Family Life Survey and have been found to be significantly associated with mortality in infancy or one of its subperiods.[6] If these determinants are also associated with the breast-feeding or sanitation variables, they could be causing (or masking) statistical associations of the mortality rates with breast-feeding and sanitation and thus confounding interpretation of these associations. Variables found in a multiple regression to contribute independently to postperinatal infant mortality were the infant's ethnicity, sex, year of birth, birth weight, and whether the preceding interpregnancy interval was less than 15 months.[6]

To take these potentially confounding factors into account, we first estimated their effects on the logit of the postperinatal infant mortality rate in a multiple regression that also included breast-feeding, the categories of toilet alone and of toilet and piped water together, and the interactions between breast-feeding and the water/toilet categories. With estimates of the effects of all of these explanatory variables, one can estimate for each child the predicted logit of mortality ($\ln [\widehat{m}/(1 - \widehat{m})]$), which then can be converted to the predicted probability of dying ($\widehat{m} = 1/[1 + e^{-\text{logit}}]$) for that child. The mean of these predicted probabilities is the mortality rate. It was identical with the actual mortality rate when each child's actual variable values were used within each of the six breast-feeding-toilet-water subsamples. To adjust mortality rates for potential confounding, we used the total sample and each infant's actual values of the potential confounding variables but set the values for breast-feeding, toilet, and water as present or absent as appropriate in each of the six breast-feeding, toilet, and water combinations described before. This procedure assured not only that the means for all the potentially confounding variables were the same in each category but also that the distributions were identical across the six categories.

These adjusted mortality rates were then used to calculate adjusted attributable and relative risks, their confidence limits, and their differences across water/toilet categories as described before. The relative risks derived from these adjusted mortality rates and the statistical significance of comparisons of these risks among water/toilet categories were less than those derived directly from the logit regression, a more accurate derivation but of more difficult exposition. Hence, we present conservative estimates here.

We examined synergism—whether the total effect of several factors together was greater than would be expected from the combination of their individual effects—by testing the statistical significance of differences in attributable risks or ratios of relative risks across water/toilet categories.

For each water/toilet category, we estimated the etiologic fraction—the percentage of deaths that could be attributed to failure to breast-feed[8]; it is the ratio of the product of the attributable risk and the prevalence of nonbreast-feeding infants to the total death rate in the category. We also calculated the prevented fraction—the proportion of deaths avoided because of breast-feeding. This was estimated like the etiologic fraction except that the prevalence of breast-feeding infants was substituted for the prevalence of nonbreast-feeding infants.

RESULTS

The actual postperinatal mortality rates for the infants in our sample according to whether they breast-fed and whether their homes had neither a toilet nor piped water, only a toilet, or both of these facilities are given in Table 1. Both the attributable and relative risks of not breast-feeding compared with breast-feeding were statistically significant for those who had neither a toilet nor piped water in their homes but were not significant if there was a toilet.

The benefits of breast-feeding were underestimated in these data, however, because higher rates of breast-feeding in Malaysia during this period were generally associated with factors that were also associated with higher rates of postperinatal mortality.[1] These factors were taken into account in Table 2, in which the mortality rates adjusted by making the distribution of potentially biasing, confounding variables identical across all six categories of breast-feeding, toilet, and water are presented. When the differences between those who did and did not breast-feed were no longer biased by these confounding variables, both the attributable and relative risk estimates of the impact of breast-feeding on postperinatal infant mortality were larger than those in Table 1. The adjusted attributable risks associated with not breast-feeding and their lower 95% confidence limits are shown in Fig 1. The attributable risks were all statistically significant (ie, their lower 95% confidence limits were greater than zero). The impact of not breast-feeding on the number of babies who died per 1,000 was lowest when the home had both piped water and a toilet (28/1,000), increased to 47/1,000 when there was only a toilet,

TABLE 1. Actual Postperinatal Infant Mortality Rates*

	Presence of Toilet and Piped Water					
	Neither Toilet or Water	No. of Infants	Toilet Only	No. of Infants	Both Toilet and Water	No. of Infants
No breast-feeding	0.196	51	0.049	223	0.027	551
Breast-feeding	0.052	907	0.030	1,860	0.017	1,549
Relative risk	3.78		1.67		1.62	
Attributable risk	0.144		0.020		0.010	

* Relative risk = ratio of mortality rate of nonbreast-fed infants to that of breast-fed infants. Attributable risk = difference in mortality rates between infants who did not breast-feed and those who did breast-feed.

TABLE 2. Adjusted Postperinatal Infant Mortality Rates*

	Presence of Toilet and Piped Water					
	Neither Toilet or Water	No. of Infants	Toilet Only	No. of Infants	Both Toilet and Water	No. of Infants
No breast-feeding	0.190	51	0.076	223	0.047	551
Breast-feeding	0.037	907	0.028	1,860	0.019	1,549
Relative risk	5.20		2.67		2.51	
Attributable risk	0.153		0.047		0.028	

* Relative risk = ratio of mortality rate of nonbreast-fed infants to that of breast-fed infants. Attributable risk = difference in mortality rates between infants who did not breast-feed and those who did.

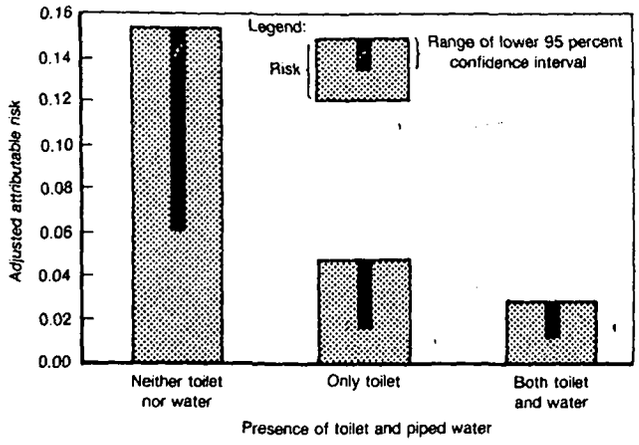

Fig 1. Adjusted attributable risk of postperinatal mortality associated with not breast-feeding in homes with different combinations of toilet and piped water.

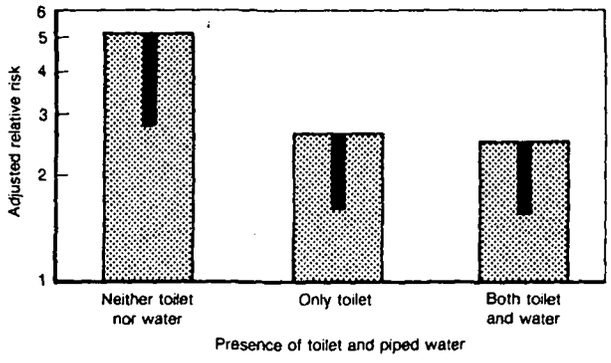

Fig 2. Adjusted relative risk of postperinatal mortality associated with not breast-feeding in homes with different combinations of toilet and piped water.

and increased more than another threefold when toilet and piped water were both absent. This last increase in the attributable risk was statistically significant—evidence of a synergistic effect on mortality between the absence of breast-feeding and the lack of a toilet in the home.

The ratio of the mortality rate of nonbreast-feeding infants to that of breast-feeding infants, the relative risk, depends not only on the absolute difference in mortality rates but also on the baseline mortality of those who breast-fed. The postperinatal infant mortality rate of breast-feeding infants was 50% higher ($P < .05$) in homes with toilets when piped water was missing than in households with both piped water and toilet sanitation, and another 30% higher ($P < .05$) when a toilet was also lacking (Table 2). However, the mortality rate increased even more rapidly across these water/toilet categories for those who did not breast-feed, especially when we compared those who had neither water nor toilet with those with toilet sanitation; as a result, the relative risks increased, even though the baseline mortalities also increased. The adjusted relative risks and their 95% lower confidence limits are shown in Fig 2. The relative risks are all statistically significant (ie, greater than 1). The relative risk was little affected by a lack of piped water if a toilet was present but doubled when both a toilet and piped water were absent. The relative risk of not breast-feeding in a home with neither piped water nor a toilet was statistically significantly higher than it was in a home that had both—evidence of synergistic effect on mortality between the absence of breast-feeding and the lack of both toilet and water together.

The etiologic fraction of deaths attributable to not breast-feeding was greatest for the category with both water and sanitation in the home, next greatest for the category in which both facilities were missing, and least in the category in which only water was lacking (Table 3). This ranking did not correspond to the ranking of the attributable risks because the ranking of the prevalences of not breast-feeding (Table 2) was opposite to the ranking of the attributable risks and often more than outweighed the effect of the attributable risk. In this sample, there were half as many infants with neither piped water nor toilet as there were in either of the other two categories. The total proportion of deaths due to not breast-feeding in this Malaysian sample was 21%.

The overall proportion of deaths that breast-feeding prevented was 61%, with the largest fraction being for infants with the worst environmental conditions. Nevertheless, this category contributed the smallest number of lives saved by breast-feeding to the total, despite the greater benefits that breast-feeding bestowed in this group, because it made up a small proportion of the total population.

TABLE 3. Etiologic Fractions of Postperinatal Infant Mortality Due to Not Breast-Feeding and Prevented Fractions Due to Breast-Feeding, According to the Availability of Piped Water and Toilet in the Home

	Presence of Piped Water and Toilet			Total
	Neither	Only Toilet	Both	
Etiologic fraction within water/toilet group	0.183	0.152	0.284	
Total etiologic fraction	0.034	0.061	0.116	0.211
Prevented fraction within water/toilet group	0.799	0.599	0.527	
Total prevented fraction	0.149	0.243	0.215	0.607

DISCUSSION

Breast-feeding was associated in these Malaysian data with improved survival, and we showed elsewhere[1] that this association was not due to flaws in data collection or analysis. Furthermore, by starting the evaluation of mortality at 1 week of age, well after breast-feeding is initiated in Malaysia, the analyses were not confounded by deaths that precluded breast-feeding. The association of breast-feeding and improved survival is also unlikely to be due to third factors that independently affect breast-feeding and infant mortality, especially because the association increases when such factors are taken into account.[1] This is demonstrated again in this paper by the comparison of the relative and attributable risks between Tables 1 and 2. Hence, this discussion presumes that this association of improved infant survival and breast-feeding is due to breast-feeding (the plausibility of this conclusion is explicated in detail elsewhere[1]) and relies on the data presented in Figs 1 and 2, which have been purged of important biasing effects of confounding factors that affect both infant mortality and breast-feeding. The discussion, therefore, relates to the situation in which only differences in breast-feeding and the availability of piped water and toilets differentiate the six postperinatal infant mortality rates (Table 2 and Figs 1 and 2).

The infant's relative risk of postperinatal mortality due to not breast-feeding (or its closely related relative odds) was twofold greater (5.20/2.51) in the absence than in the presence of toilet and piped water—a synergistic effect. The cause of the greater protective effect of breast-feeding in poor environmental situations cannot be elucidated from the analyses presented here. It could be that contaminated water and foods are not ingested because the child is only receiving breast milk, or it could be that breast milk per se is nutritionally superior and/or improves immunity and resistance to disease and decreases the severity and duration of disease episodes. Some insight is provided by multivariate analyses of these data of the associations of durations of unsupplemented and supplemented breast-feeding in the first week, the subsequent 3 weeks, and the next 5 months of infancy with mortality during the subsequent period of infancy.[9] That study showed that the younger the infant, the greater the benefits of breast-feeding. As found in this study, the benefits were strongest for infants in homes without piped water or toilet sanitation and weakest in homes with both. Unsupplemented breast-feeding during the first half of infancy protected better than supplemented. Nonetheless, supplemented breast-feeding had significant positive benefits, suggesting that breast-feeding does more than simply prevent the ingestion of contaminated water and foods in homes lacking toilets and piped water.

The synergism of not breast-feeding with the absence of piped water and toilet has a perfect symmetry: The detrimental effect of not having a toilet in the home was much greater where an infant was not breast-fed. This may explain some of the failures to identify reductions in infant mortality after improving sanitation and water in populations that breast-feed.[10]

The absence of piped water in homes with toilets appears to have little, if any, synergism with the absence of breast-feeding. The converse cannot be tested for lack of sufficient numbers of non-breast-feeding children born into households with piped water but without a toilet. For the same reason, one cannot ascertain for this sample whether absence of water alone would have the same synergistic effect with the absence of breast-feeding as does the absence of a toilet in increasing infant mortality.

Although the relative risk gives insight into the risk each baby suffers who is not breast-fed, the attributable risk shows the excess mortality actually observed between babies who did and did not breast-feed. Breast-feeding saved lives in every water/toilet category considered. The adjusted attributable risk of increased mortality from not breast-feeding was more than threefold greater ($P < .05$) in homes without a toilet than in those with, which is an even greater synergism than when the benefits are expressed as relative risks.

Throughout the world, socioeconomic development was almost universally accompanied by a decrease in breast-feeding through the middle 1970s. But water and sanitation also improve during development. Socioeconomic development in what is today peninsular Malaysia was no exception. Because nonbreast-feeding is less pernicious in the presence of piped water and toilet sanitation, it might have been that the decrease in breast-feeding had a minimal effect because it happened in those families with adequate water and sanitation. That was not the case, however: The infant mortality decrease throughout the period of 1946 to 1975 due to water and sanitation improvements was more than offset by the detrimental effects of the decline in breast-feeding.[11]

Our finding of a threefold synergism in the attributable risks implies that, if the cost per infant were the same, the returns from increasing and maintaining the prevalence of breast-feeding among women who live in poor environmental sit-

uations would be three times greater than among those living in better situations. One might conclude from such a finding that targeting a program to increase breast-feeding to those with neither piped water nor toilet sanitation would be likely to be more effective at reducing mortality than a national, untargeted program. As is shown in Table 3, however, this is not necessarily correct. The proportion of deaths attributable to lack of breast-feeding (the etiologic fraction) was in fact substantially larger for those with both toilet and piped water (0.28) than for those with neither (0.18). This finding appears peculiar, given the much larger beneficial attributable risk of breast-feeding where sanitation was lacking and the fact that the attributable risk contributes importantly to the etiologic fraction. In these data, however, the prevalence of nonbreast-feeding infants was five times greater among those living in the better environmental conditions (0.26) than those in the worst (0.05). Furthermore, those in the best environmental conditions were twice as numerous as those in the worst, so that the proportion of deaths in the total population due to the synergism of poor sanitary environment and not breast-feeding (0.03) was about a fourth as high as that found in the best environment (0.12). The total proportion of deaths due to not breast-feeding, the total etiologic fraction, was 21%. Hence, if the total cost of targeting a breast-feeding promotion program at those with neither piped water nor toilet sanitation were the same as at those with these amenities, the benefit to cost ratio would be higher for the latter because of their greater number of nonbreast-feeding infants.

The total proportion of deaths saved because of breast-feeding, the total prevented fraction, was 61%. In contrast to the etiologic fraction, the prevented fraction was much higher (0.80) among those who were worse off environmentally than among those who were best off (0.53). Yet, even with such a difference, the overall contribution of breast-feeding to saving lives was larger in the two groups with some toilet sanitation because they represented a larger proportion of the Malaysian population.

In conclusion, in peninsular Malaysia during the period covered by these data, the failure to breast-feed in homes that lacked piped water and sanitation entailed twice the risk of dying in postperinatal infancy as in homes that had both. A decline in breast-feeding is therefore particularly pernicious where water and sanitation are poor. However, the survival benefits of breast-feeding are important enough to warrant fostering breast-feeding for all infants, even where water and sanitation are good. In this data set, more infant lives were lost because of not breast-feeding (or saved because of breast-feeding) in homes with good water and sanitation than in those where both were lacking, because the latter were rare. Therefore, in settings like those covered by these data, breast-feeding should be fostered for its life-saving effects in all homes. However, in poorer countries with lower prevalence of modern sanitation and water supply, the results reported here suggest that serious consideration be given to targeting programs to foster breast-feeding specifically to areas where water and sanitation are poor, especially where breast-feeding is infrequent or decreasing in frequency.

ACKNOWLEDGMENTS

This paper derives from research supported by grant AID-OTR-1822 from the Agency for International Development to The RAND Corporation, by grant RO1 HD20029-01A1 to RAND from the National Institute of Child Health and Human Development, and by the Cornell Nutrition Surveillance Program (grant AID-DSAN-CA-0240).

It is also a report of the Cornell University Agricultural Experiment Station, Division of Nutritional Sciences.

The authors thank Christine Peterson for programming assistance; Dorothy Fernandez, of the Department of Statistics of the Government of Malaysia, and Dr Nyle Spoelstra and Robert Jones and their staffs at Survey Research Malaysia, for their collaboration in gathering the data analyzed in this study; and Hal Morgenstern for suggestions.

REFERENCES

1. Habicht J-P, DaVanzo J, Butz WP: Does breastfeeding really save lives, or are apparent benefits due to biases? *Am J Epidemiol* 1986;123:279–290
2. Foege WH: Report of the task force on the assessment of the scientific evidence relating to infant-feeding practices and infant health. *Pediatrics* 1984;74(suppl):579–762
3. Clemens JD, Stanton B, Stoll B, et al: Breastfeeding as a determinant of severity in Shigellosis. *Am J Epidemiol* 1986;123:710–720
4. Butz WP, DaVanzo J: *The Malaysian Family Life Survey: Summary Report.* Santa Monica, CA, The RAND Corporation, R-2351-AID, 1978
5. Habicht J-P, DaVanzo J, Butz WP, et al: The contraceptive role of breastfeeding. *Population Studies* 1985;39:213–232
6. DaVanzo J, Butz WP, Habicht J-P: How biological and behavioural influences on mortality in Malaysia vary during the first year of life. *Population Studies* 1983;37:381–402
7. MacMahon B, Pugh TH: *Epidemiology: Principles and Methods.* Boston, Little, Brown & Co, 1979
8. Kleinbaum DG, Kupper LL, Morgenstern H: *Epidemiologic Research.* Belmont, CA, Wadsworth, 1982
9. Butz WP, Habicht J-P, DaVanzo J: Environmental factors in the relationship between breastfeeding and infant mortality: The role of sanitation and water in Malaysia. *Am J Epidemiol* 1984;119:516–525
10. Esrey SA, Habicht J-P: Epidemiologic evidence for health benefits from improved water and sanitation in developing countries, *Epidemiol Rev* 1986;8:117–128
11. DaVanzo J, Habicht J-P: Infant mortality decline in Malaysia, 1946–1976: The role of changes in variables and changes in the structure of relationships. *Demography* 1986;23:143–160